



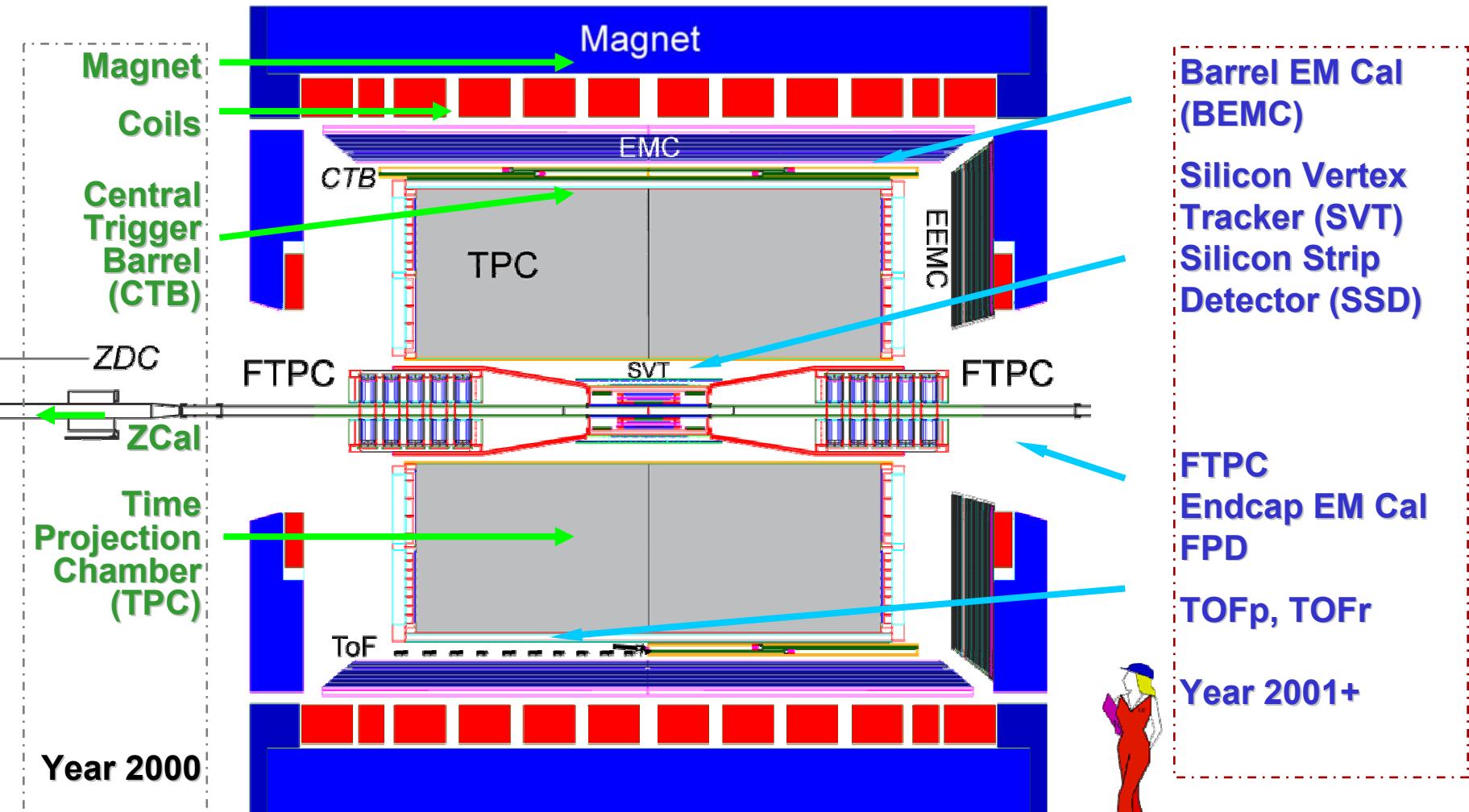
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# Highlights from STAR

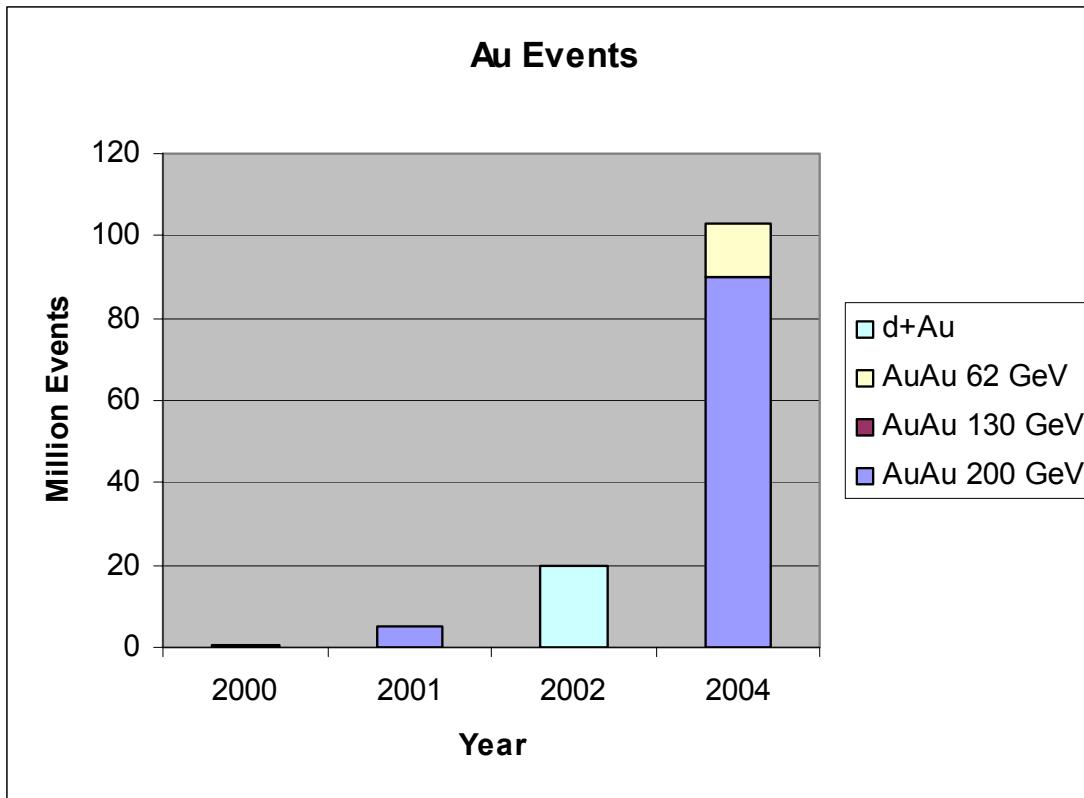
James Dunlop  
Brookhaven National Laboratory  
for the STAR Collaboration



# The STAR Detector

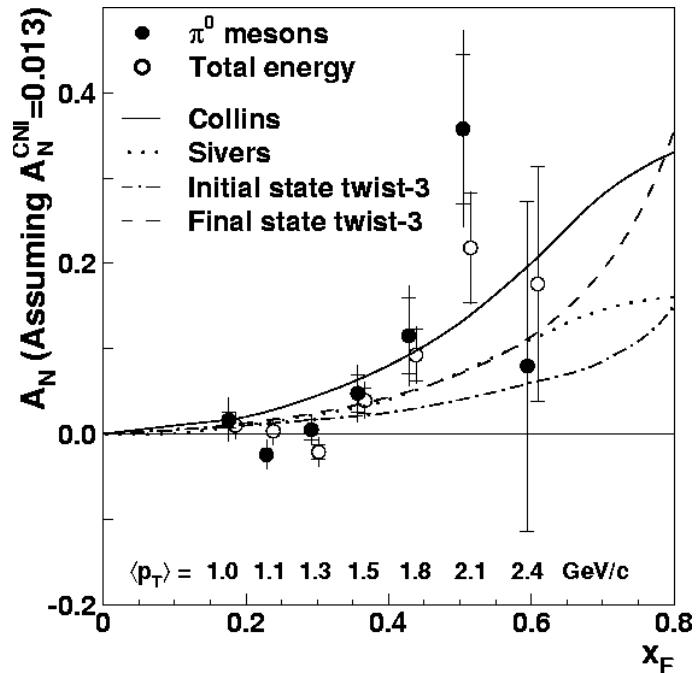
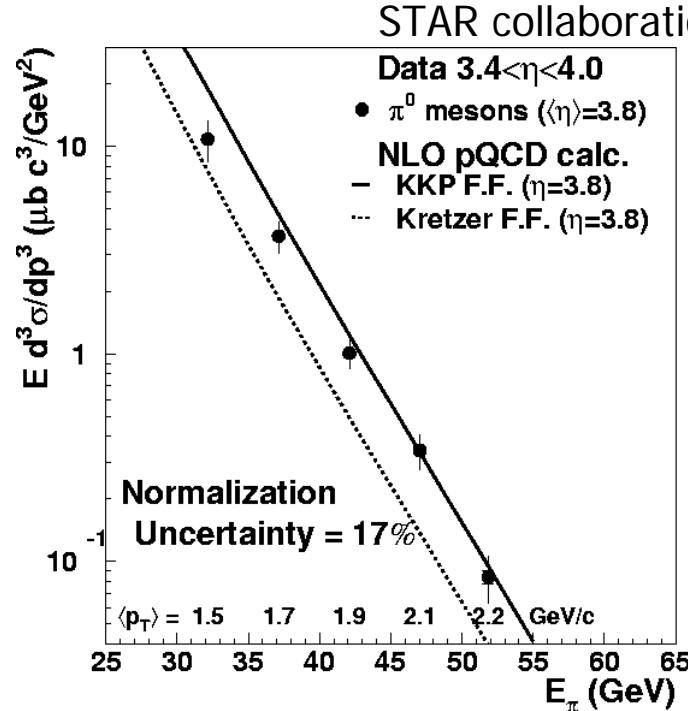


# Au+X Datasets



- ❑ This year: extremely successful run, all BUR goals substantially met
- ❑ Greater than order of magnitude increase in dataset
- ❑ Significant new challenge for data processing

# Spin: Forward $\pi^0$



- pQCD calculations consistent with measured large- $\eta$   $\pi^0$  cross sections
- Large transverse single-spin effects observed for  $\sqrt{s} = 200 \text{ GeV}$   $pp$  collisions

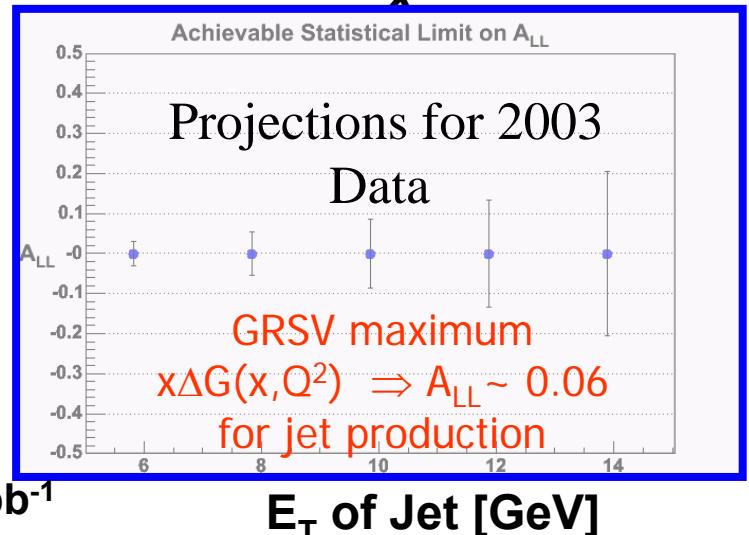
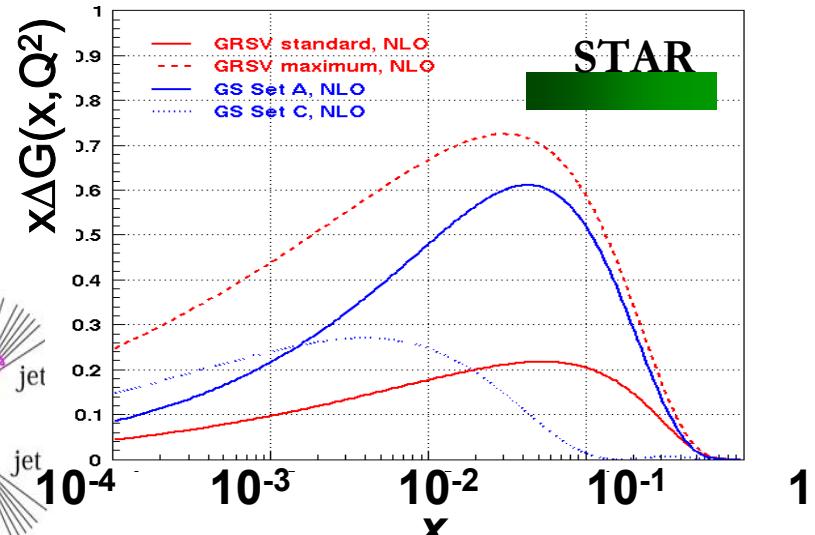
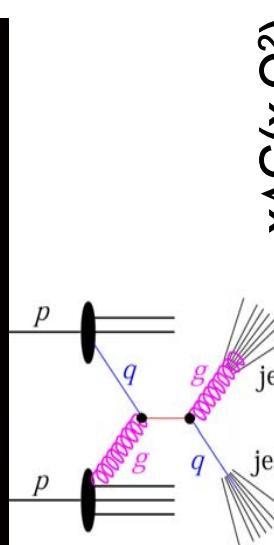
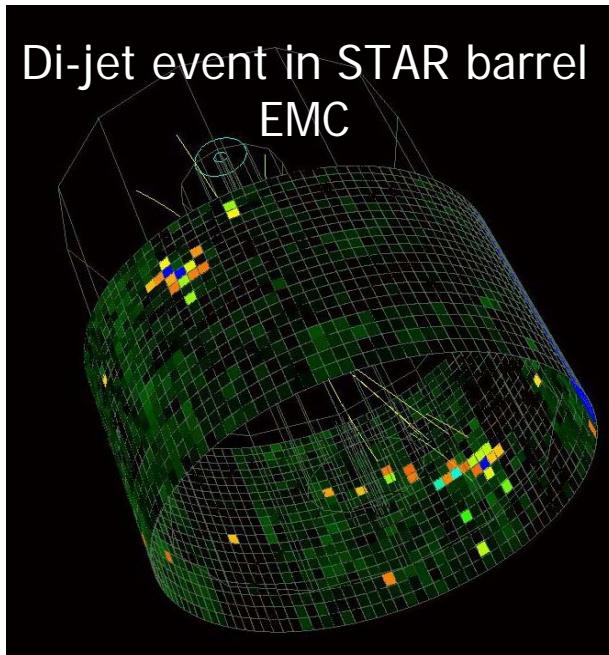
Collins effect  $\Rightarrow$  transversity

Sivers effect  $\Rightarrow$  orbital angular momentum

Additional measurements required to disentangle contributions

# $A_{LL}$ for $\vec{p} + \vec{p} \rightarrow jets$ at $\sqrt{s} = 200$ GeV

⇒ sensitivity to gluon polarization



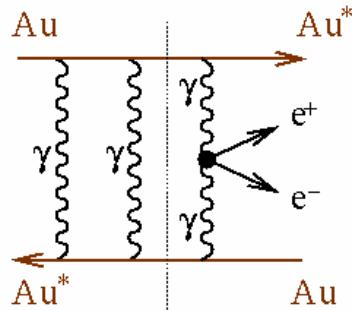
Achieved in 2003:

- . Ave Polarization / Beam ~ 0.25
- . RHIC Delivered Integrated L ~ 0.4 pb<sup>-1</sup>

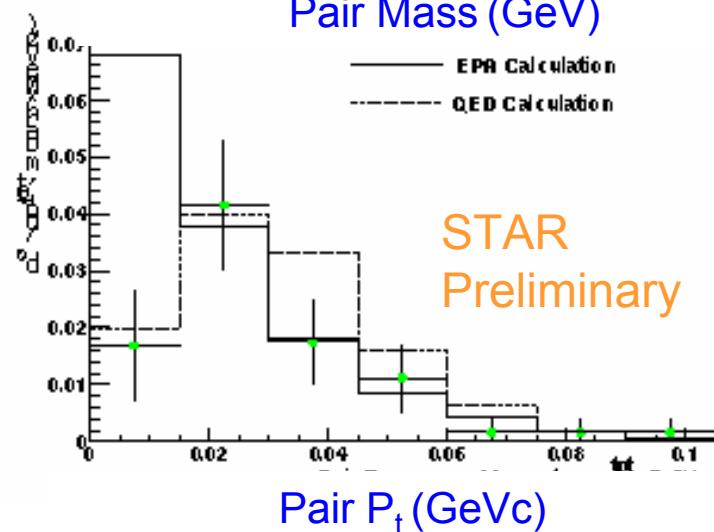
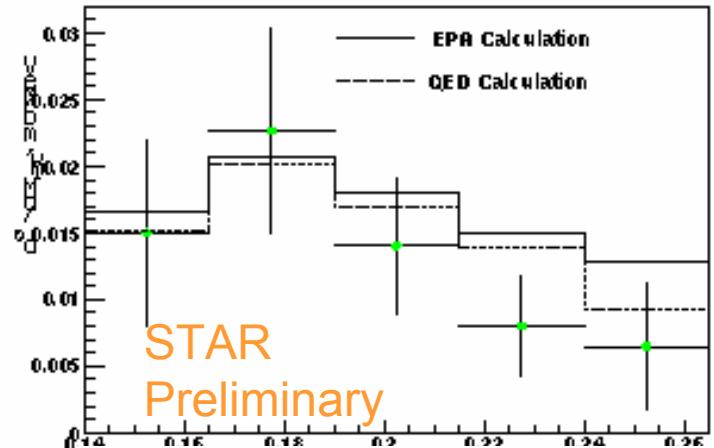
Goal for 2005

- . Ave Polarization / Beam ~ 0.40
- . RHIC Delivered Integrated Luminosity ~ 5 pb<sup>-1</sup>

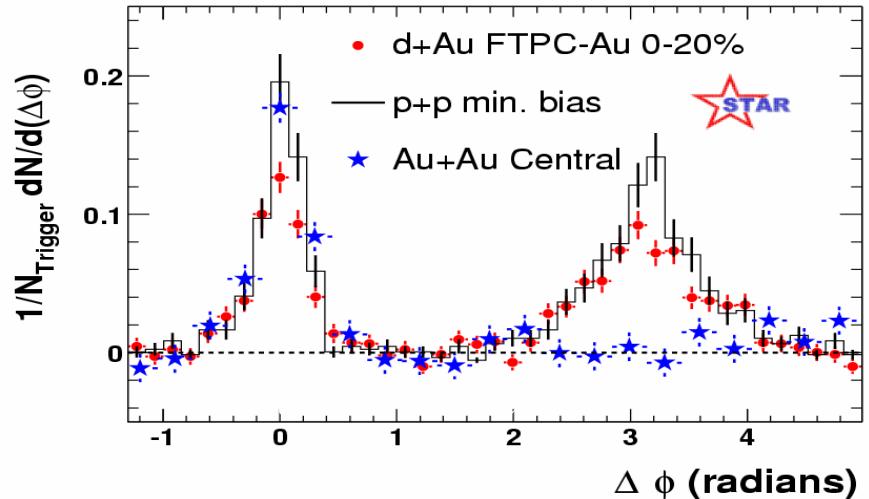
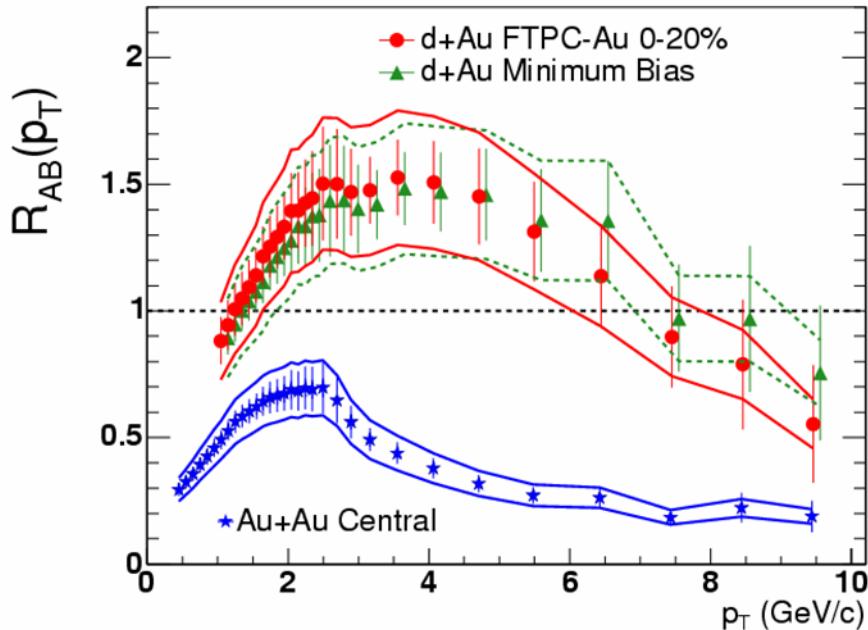
# UPC collisions: QED



- $e^+e^-$  pairs accompanied by nuclear breakup
- Strong fields:  $Z\alpha_{EM} \sim 0.6$ 
  - Higher order corrections?
- Full lowest-order QED necessary
- Limits set on higher order corrections
- Further topic: exotic meson spectroscopy



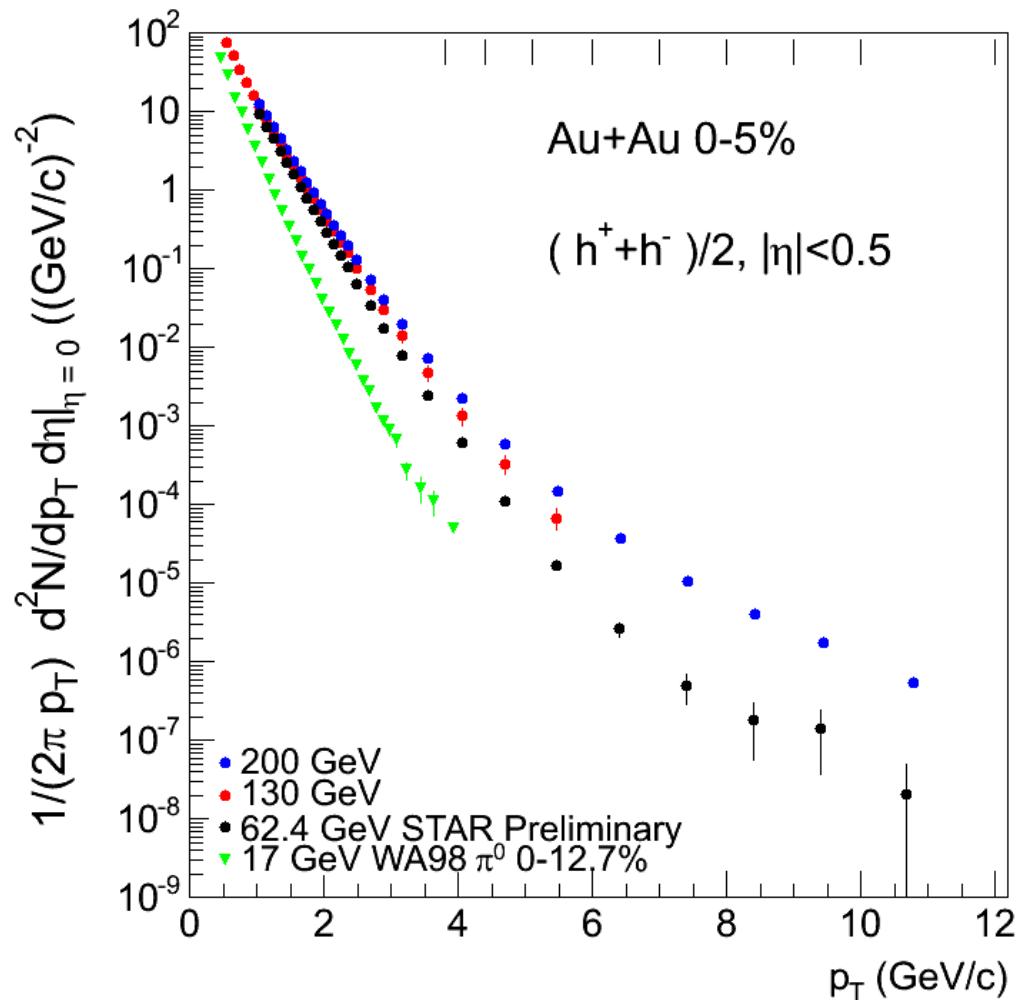
# Jet Quenching



- Au + Au,  $R_{AA} \ll 1$ ; d+Au,  $R_{dAu} > 1$
  - p+p, away side jet exists
  - Au + Au, away-side correlation suppressed
  - d+Au, away-side correlation exists
- jet quenching ?

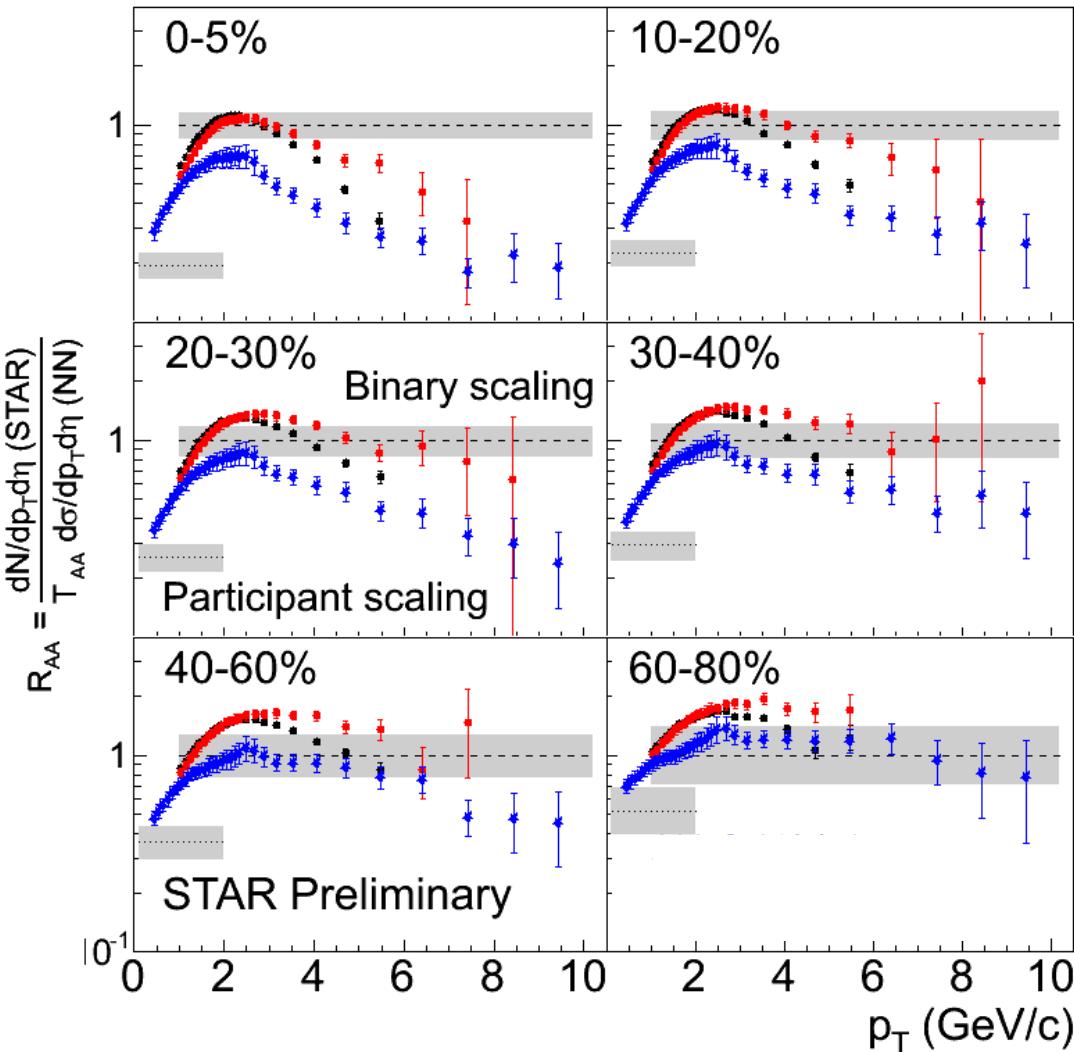
J. Adams et al., Phys. Rev. Lett. 91, 072304 (2003).

# Inclusive hadrons: Evolution with $\sqrt{s}$



**Dominant feature: order of magnitude increase at high  $p_T$**

# Inclusive hadron suppression



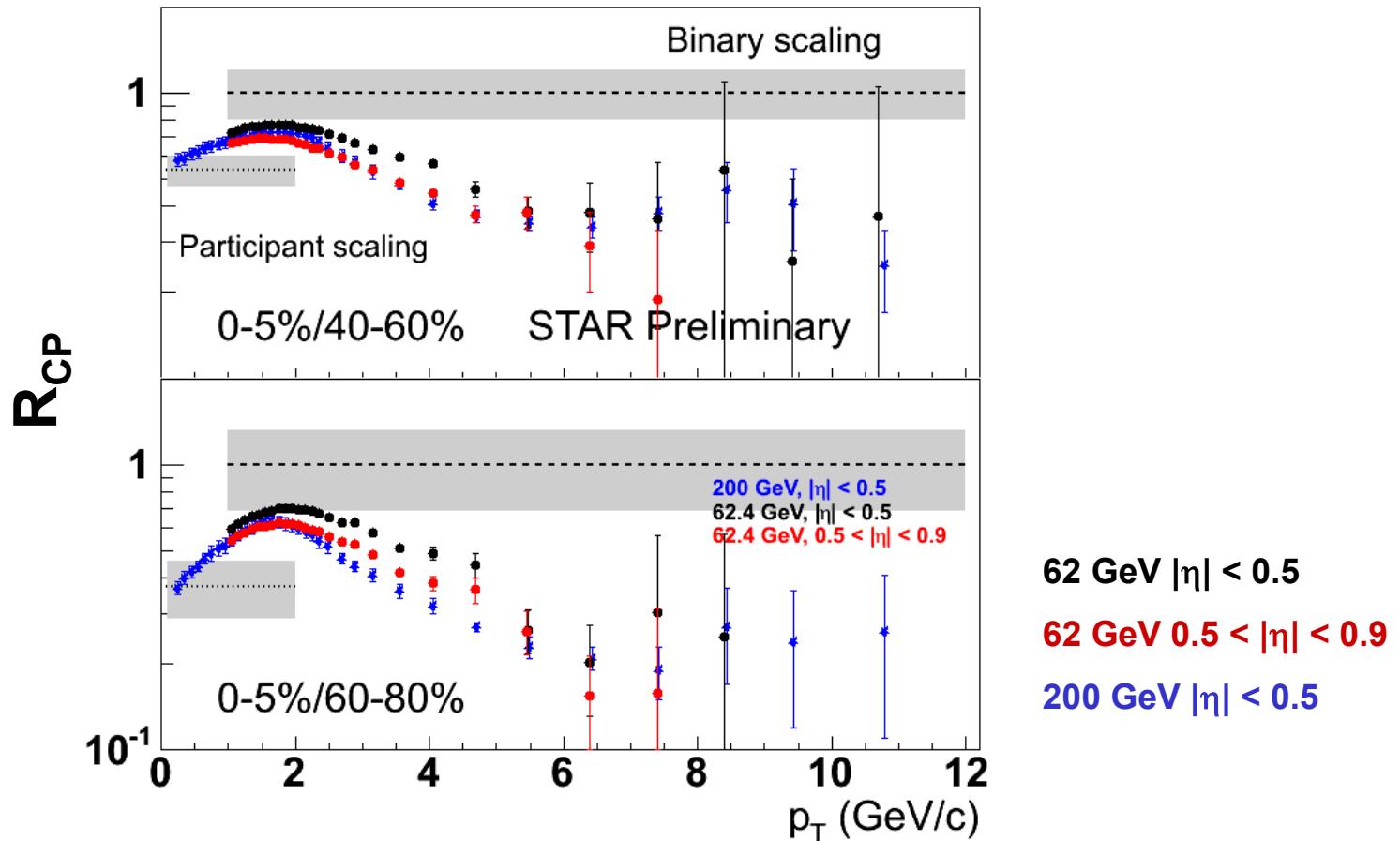
- 2  $\eta$  bins, driven by p+p
  - $\eta = 0$ :  $p_T < \sim 6 \text{ GeV}$
  - $\eta = 0.7$ :  $p_T < \sim 10 \text{ GeV}$
- Significant suppression seen at **62** and **200** GeV
- 1/3 of dataset: quantitative treatment awaits full analysis

**200 GeV  $|\eta| < 0.5$**

**62 GeV  $|\eta| < 0.5$**

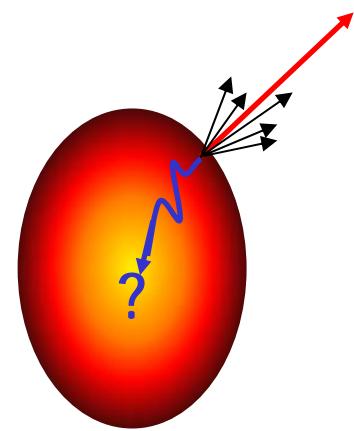
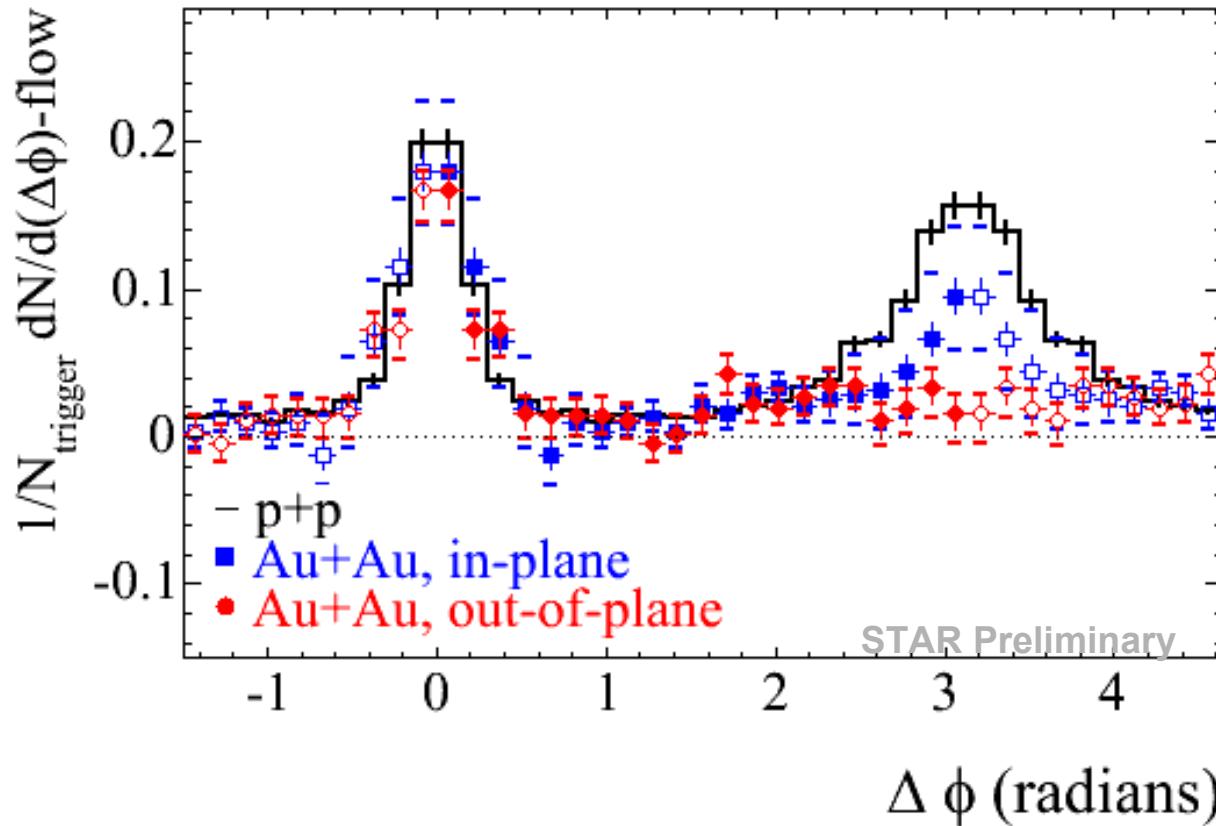
**62 GeV  $0.5 < |\eta| < 0.9$**

# $R_{CP}$ : Centrality dependence



- Significant suppression using peripheral as reference relative to both binary and participant scaling

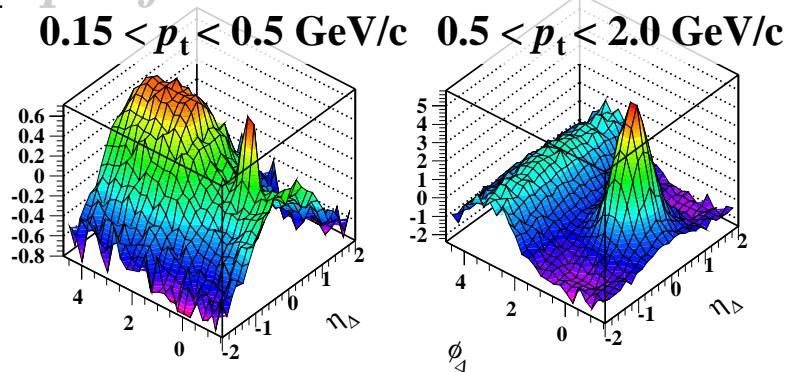
# Geometry of away-side suppression



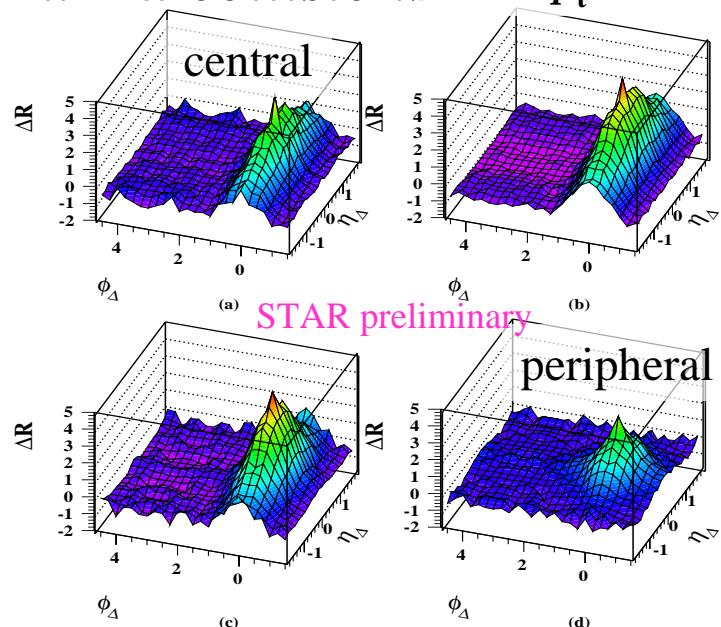
- Au+Au: Away-side suppression is larger in the out-of-plane direction compared to in-plane**
  
- Geometry of dense medium imprints itself on correlations**

# Number Correlations at Lower $p_T$

*p-p reference*



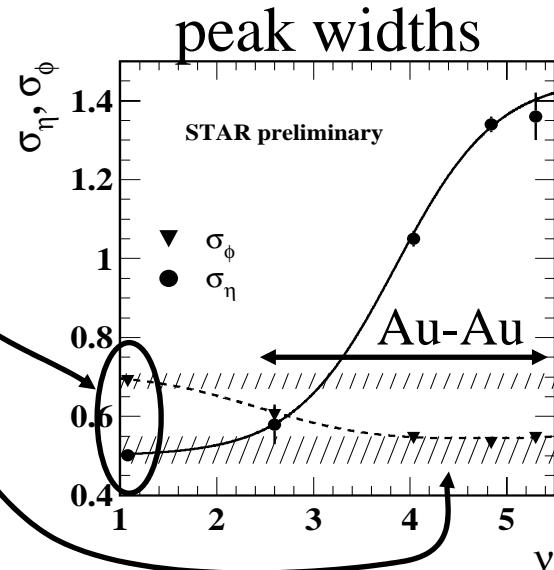
*Au-Au collision*  $0.15 < p_t < 2.0 \text{ GeV}/c$



parton modification in expanding color medium:

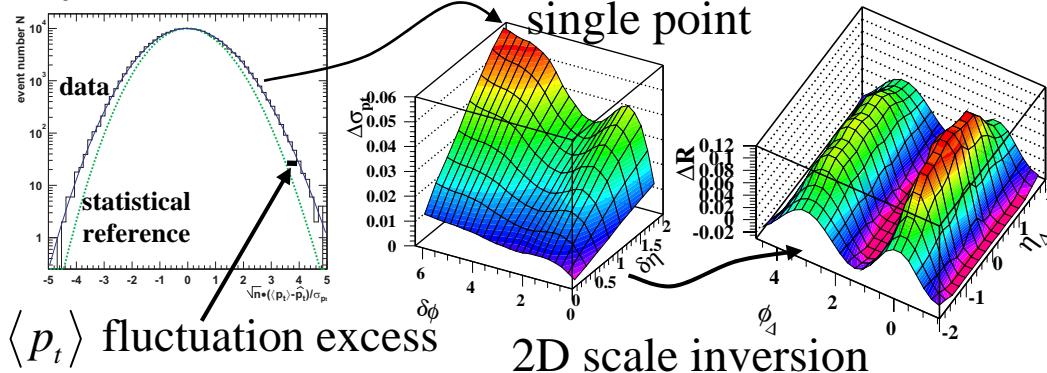
- elongation on  $\eta_\Delta$
- narrowing on  $\phi_\Delta$

*soft partons probe color medium properties*



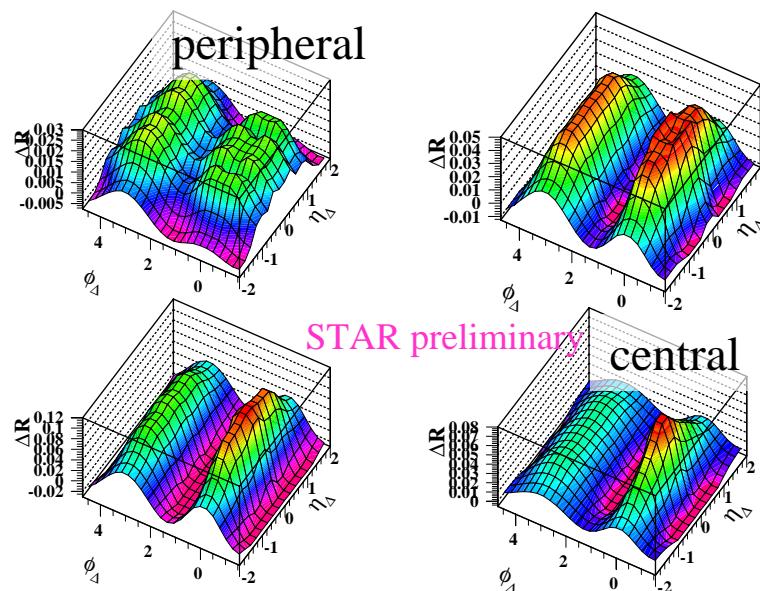
# $\langle p_T \rangle$ Fluctuations → Correlations

## $\langle p_t \rangle$ fluctuation inversion



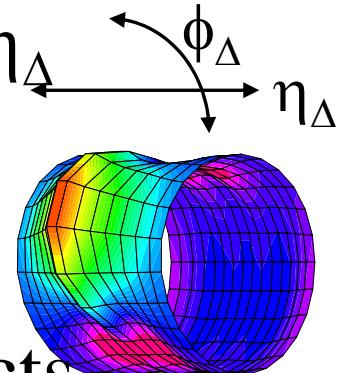
fluctuation scale  
dependence → two-  
particle correlations

## 200 GeV Au-Au data



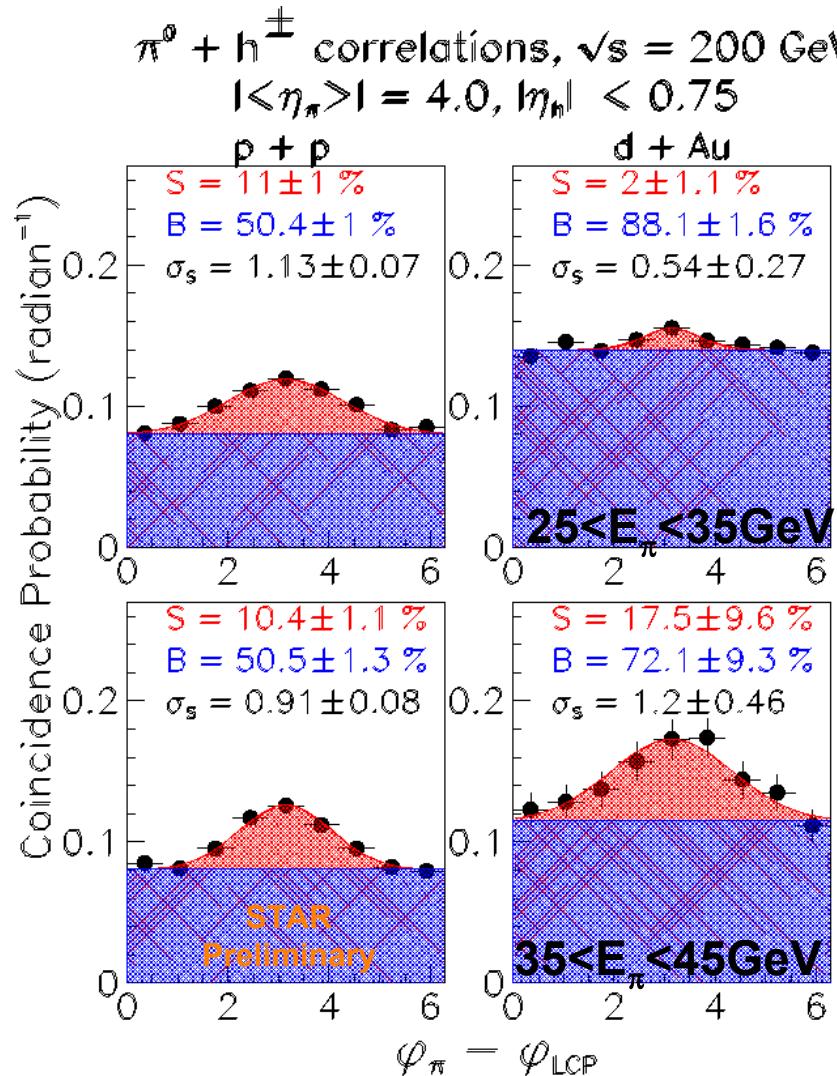
minijet dissipation &  
velocity/temperature structure:

- elongation on  $\eta_\Delta$
- necking on  $\phi_\Delta$



soft partons as  
extended objects

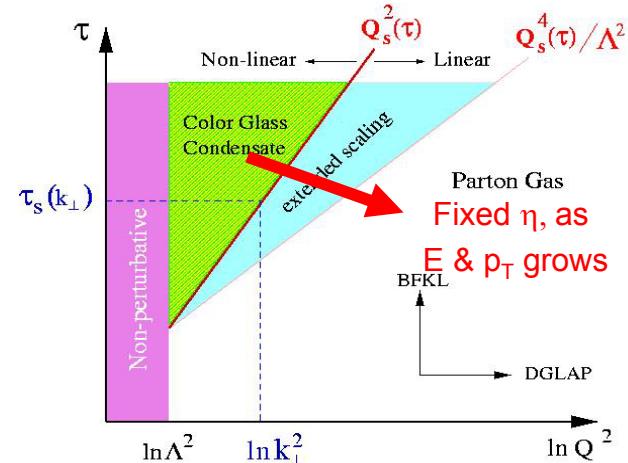
# dAu Correlations: probing low x



Statistical errors only

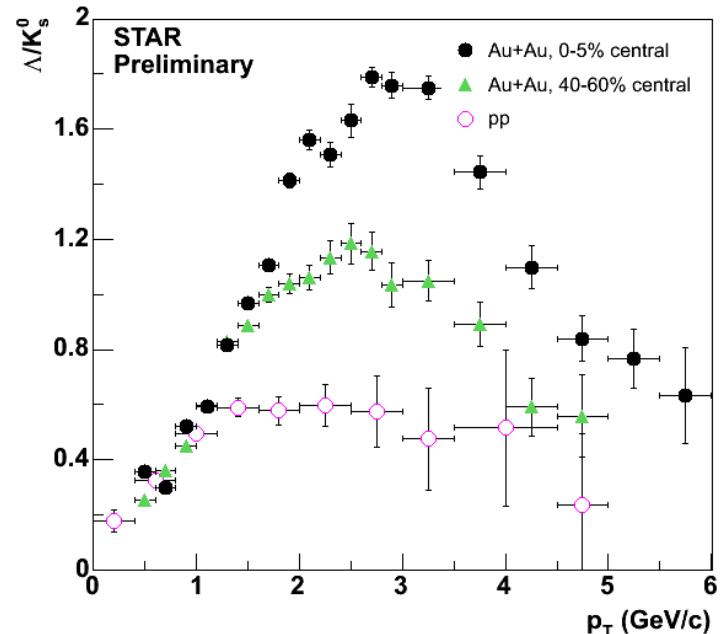
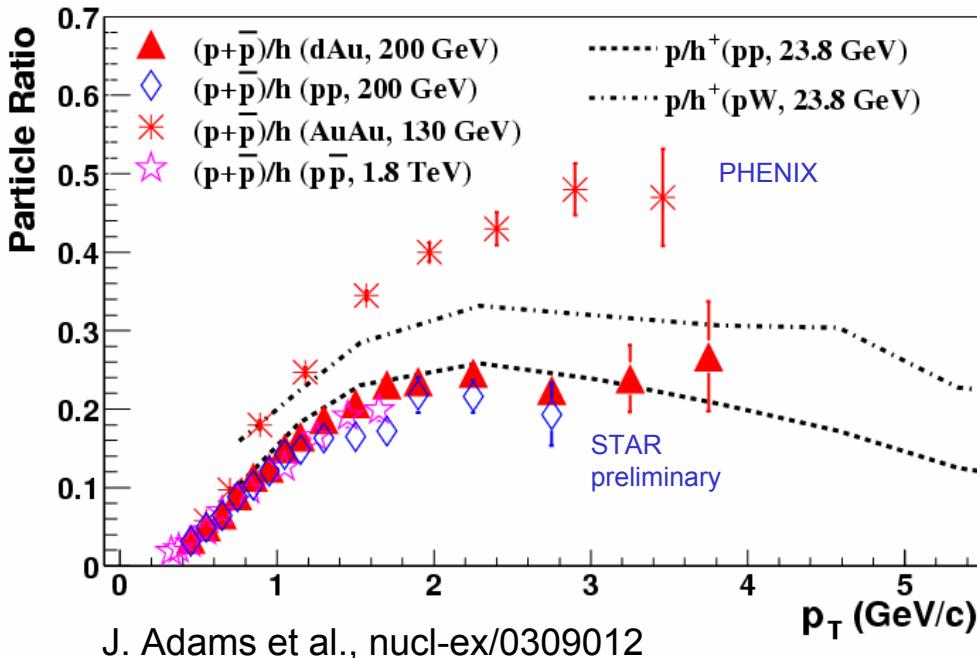
- Large  $\Delta\eta$   $\pi^0+h^\pm$  correlations
- Suppressed at small  $< x_F >$ ,  $< p_{T,\pi} >$

Consistent with CGC picture



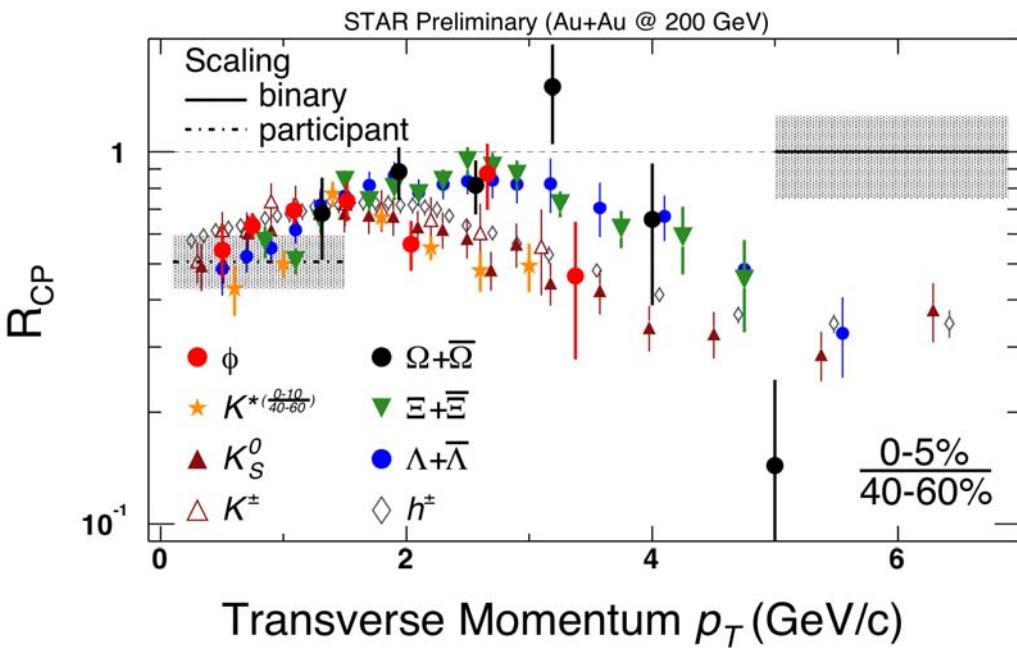
- Consistent in d+Au and p+p at larger  $< x_F >$  and  $< p_{T,\pi} >$
- as expected by HIJING

# Baryon Enhancement



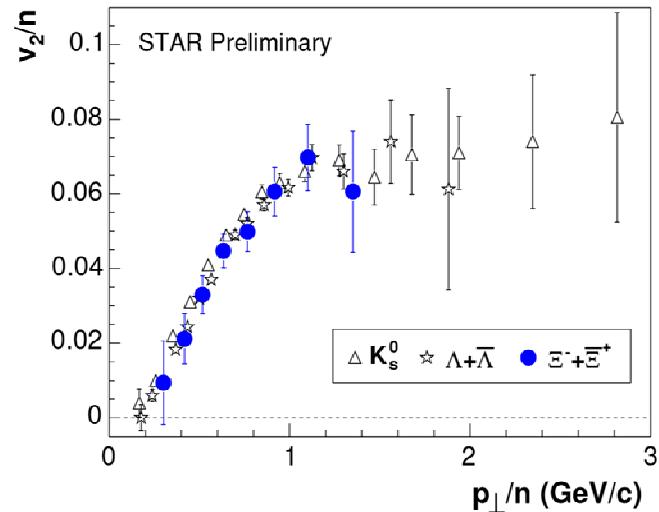
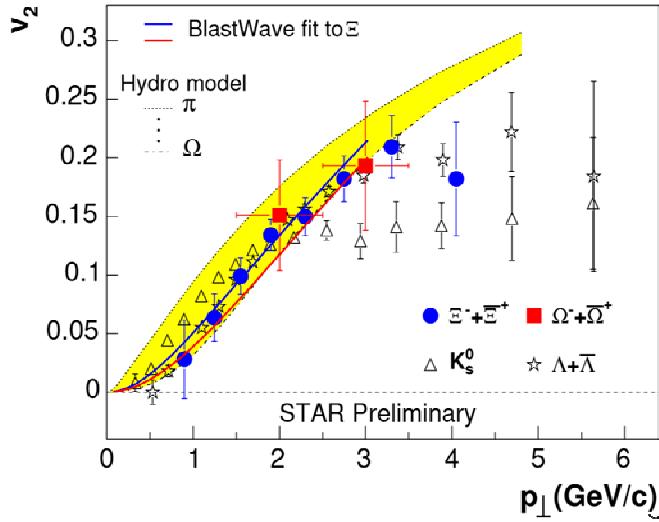
- Simple fragmentation picture fails for  $p_T$  less than ~6 GeV/c
- $p+p\bar{p}/h$  enhancement in Au + Au not fully explained by Cronin effect
- Strong baryon/meson modification in Au + Au also in  $\Lambda/K_s^0$  ratio

# $R_{CP}$ of Strange Hadrons



- Two groups ( $2 < p_t < 6 \text{ GeV}/c$ ):  
 -  $K_s^0, K^\pm, K^*, \phi \rightarrow \text{mesons}$   
 -  $\Lambda, \Xi, \Omega \rightarrow \text{baryons}$
- dependence on number of valence quarks
- limited to  $p_t < 6 \text{ GeV}/c$  ?
- hadron production from quark recombination/coalescence ?

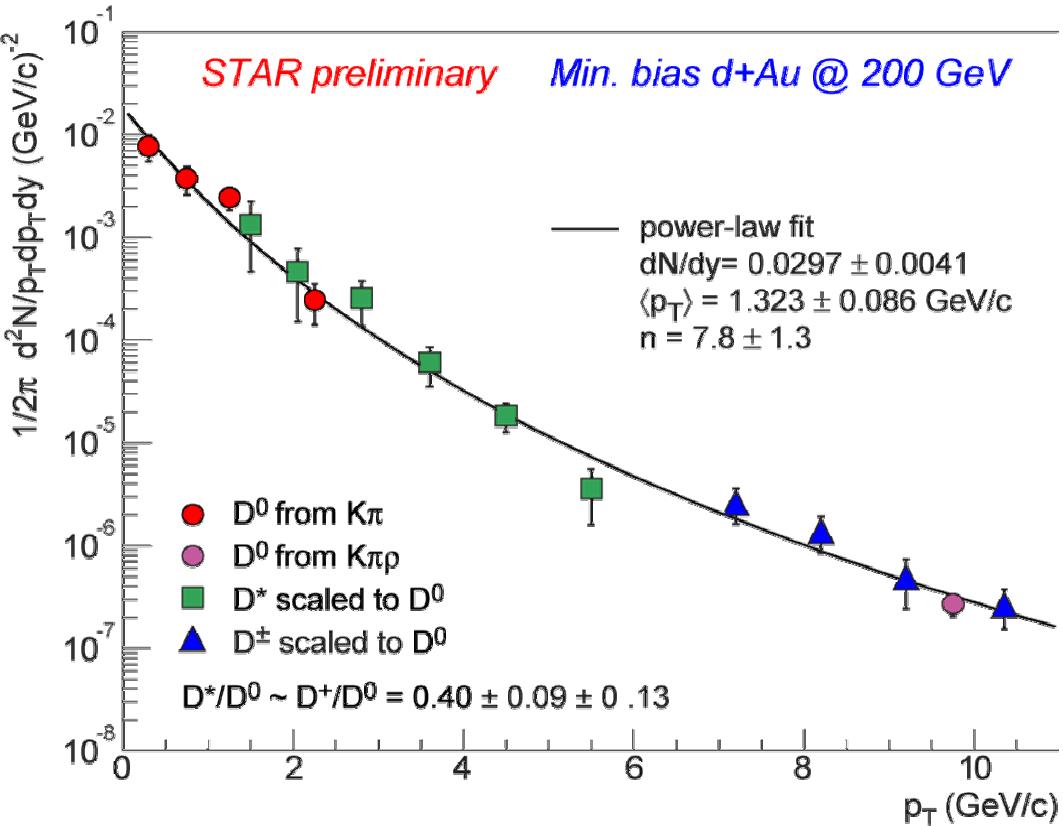
# $v_2$ : Scaling



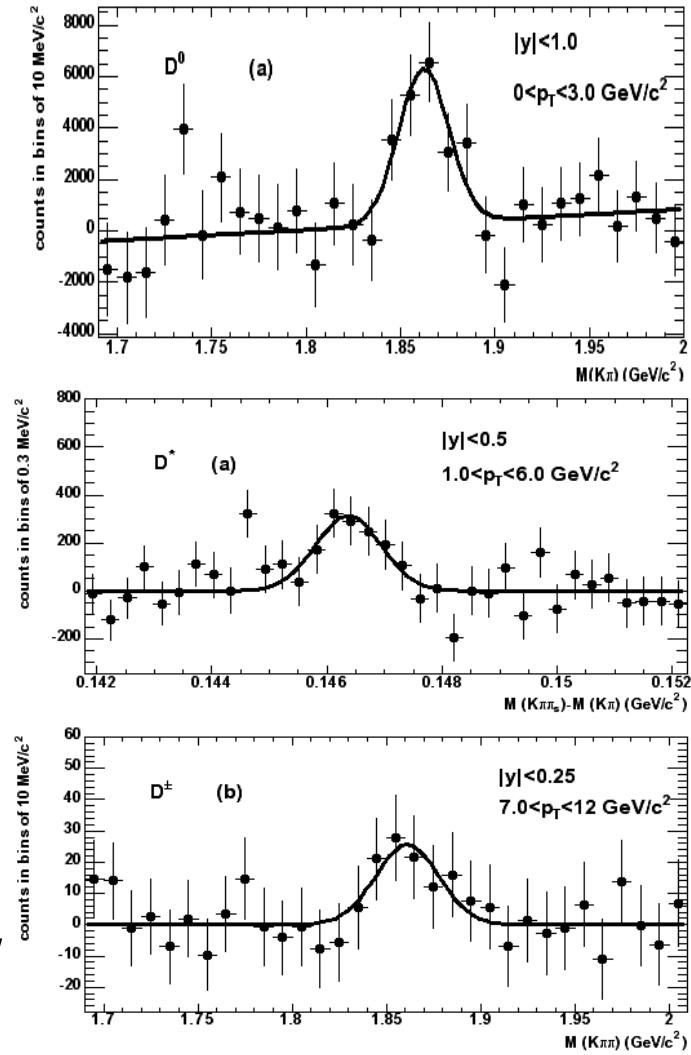
- Meson – baryon Effect ?
- Exp. data consistent with quark recombination/coalescence scenario
- Further tests:  $\phi$ ,  $\rho^0$ ,  $K^*$ , ...

S.A. Voloshin, Nucl. Phys. A715, 379 (2003).  
 Z. Lin et al., Phys. Rev. Lett., 89, 202302 (2002).  
 R. Fries et al., nucl-th/0306027.  
 D. Molnar and S.A. Voloshin, PRL 91, 092301(2003).

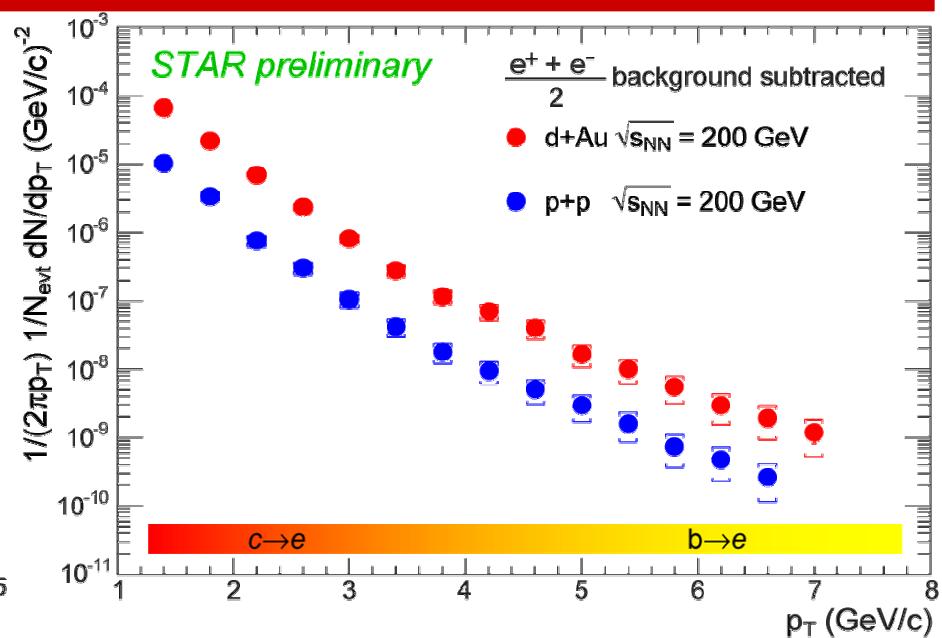
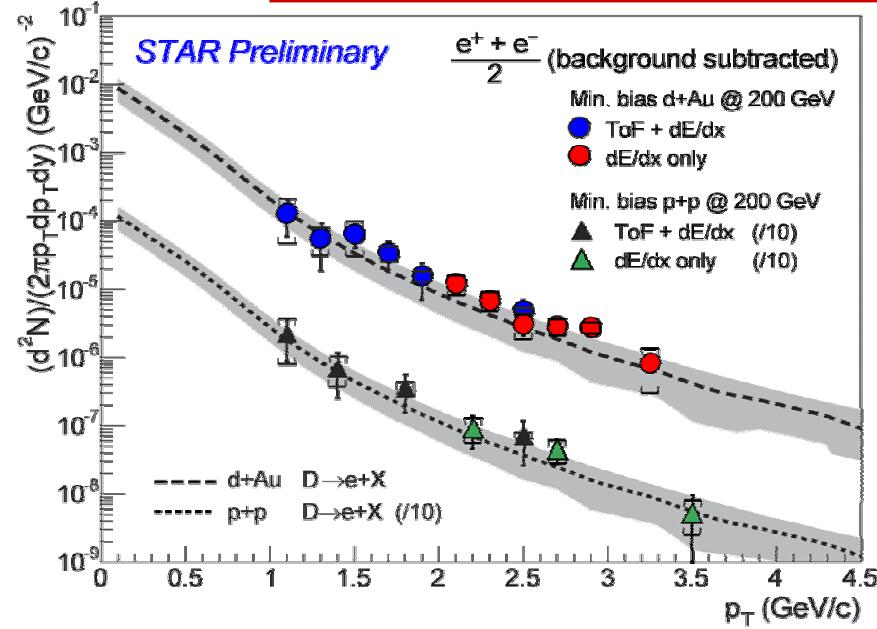
# First D Measurement at RHIC



- $D^0$ ,  $D^\pm$ ,  $D^*$  spectra from d+Au
- Cover range  $0.2 < p_T < 11 \text{ GeV}/c$
- Necessary baseline for Au+Au

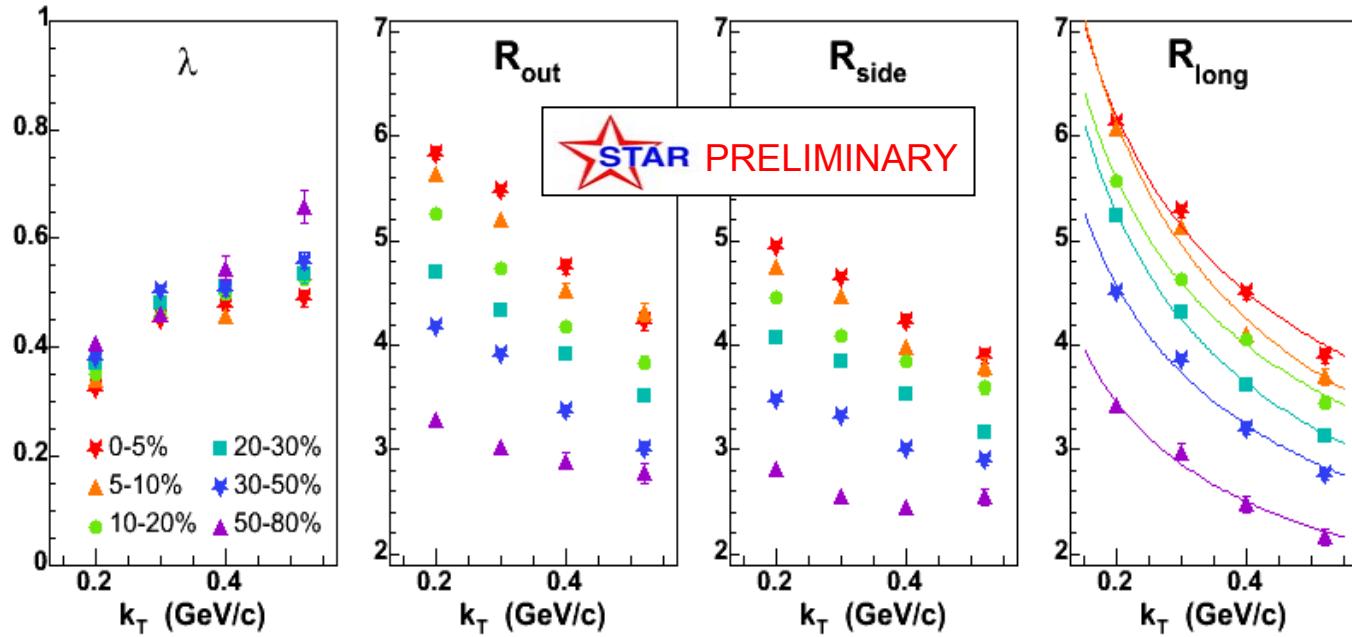


# Heavy Flavor D,B → e + X



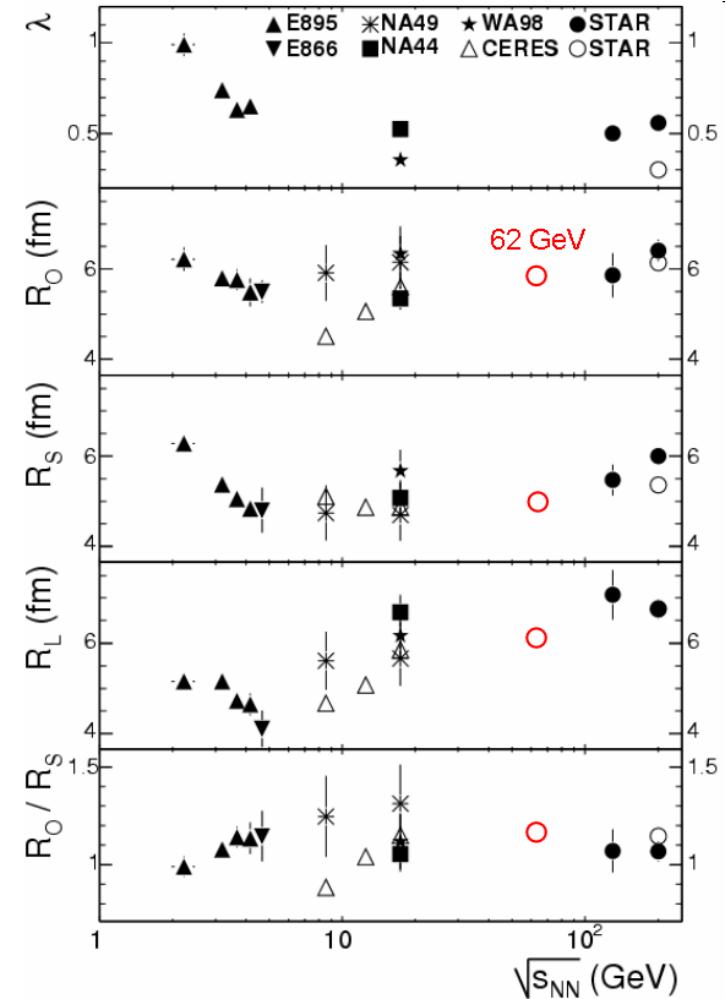
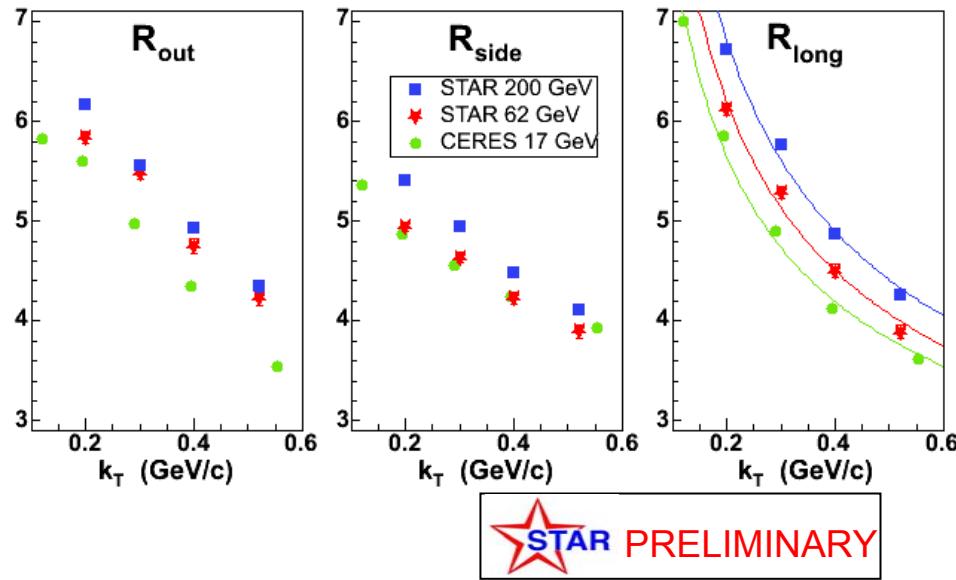
- (e<sup>+</sup> + e<sup>-</sup>)/2 spectrum, background subtracted
- e-PID by TOF, dE/dx and EMC, measurements consistent
- Consistent with measured D meson yield
- PYTHIA:    c → e, dominates at p<sub>T</sub> ~ 2-4 GeV/c  
 b → e, dominates at p<sub>T</sub> > 4-5 GeV/c

# $\pi$ HBT interferometry @ 62 GeV



- HBT probes space-time evolution of system and system size at freeze-out
- Studies at  $\sqrt{s}=130, 200$  GeV yielded similar HBT radii to SPS energies (“HBT puzzle”)
- Severe challenge to hydrodynamic calculations
- At an intermediate energy, a larger expansion time might point to a long-lived mixed phase

# HBT from SPS to RHIC



- Systematics of central 0-5% events
- Fully consistent Coulomb treatment in  $k_T$  dependence
- No sign of qualitatively different expansion dynamics at 62 GeV
- Continues to be a severe challenge



# Outlook

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- Wealth of results from STAR
  - Critical assessment QGP whitepaper: June
- Current dataset: qualitative increase in statistical power
  - Extend  $p_T$  reach well into perturbative regime
    - Extensive correlation analyses
  - Charm identification and suppression (or lack)
  - Extend particle identification @ intermediate  $p_T$ 
    - Test  $v_2$  and  $R_{CP}$ : where does it scale, and where not?
  - Extend systematics with 62 GeV
    - Are there any qualitative differences?
    - Can quantitative differences be explained?



# The STAR Collaboration: 51 Institutions, ~ 500 People

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## U.S. Labs:

Argonne, Lawrence Berkeley, and Brookhaven National Labs

## U.S. Universities:

UC Berkeley, UC Davis, UCLA, Caltech, Carnegie Mellon, Creighton, Indiana, Kent State, MIT, MSU, CCNY, Ohio State, Penn State, Purdue, Rice, Texas A&M, UT Austin, Washington, Wayne State, Valparaiso, Yale

## Brazil:

Universidade de Sao Paolo

## China:

IHEP - Beijing, IPP - Wuhan, USTC, Tsinghua, SINR, IMP Lanzhou

## Croatia:

Zagreb University

## Czech Republic:

Nuclear Physics Institute

## England:

University of Birmingham

## France:

Institut de Recherches Subatomiques Strasbourg, SUBATECH - Nantes

## Germany:

Max Planck Institute – Munich  
University of Frankfurt

## India:

Bhubaneswar, Jammu, IIT-Mumbai, Panjab, Rajasthan, VECC

## Netherlands:

NIKHEF

## Poland:

Warsaw University of Technology

## Russia:

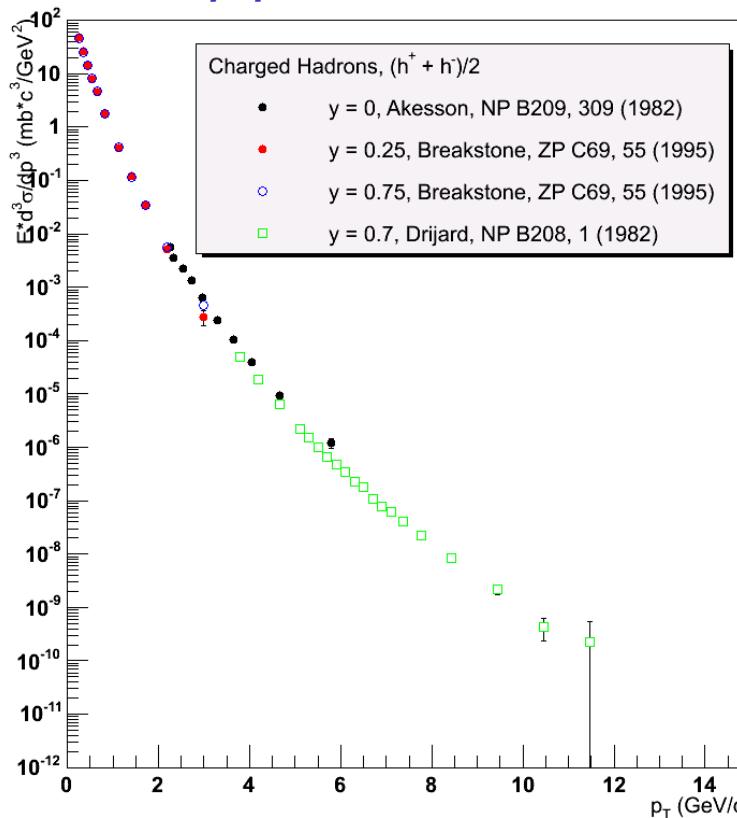
MEPHI – Moscow, LPP/LHE JINR – Dubna, IHEP – Protvino

## Switzerland:

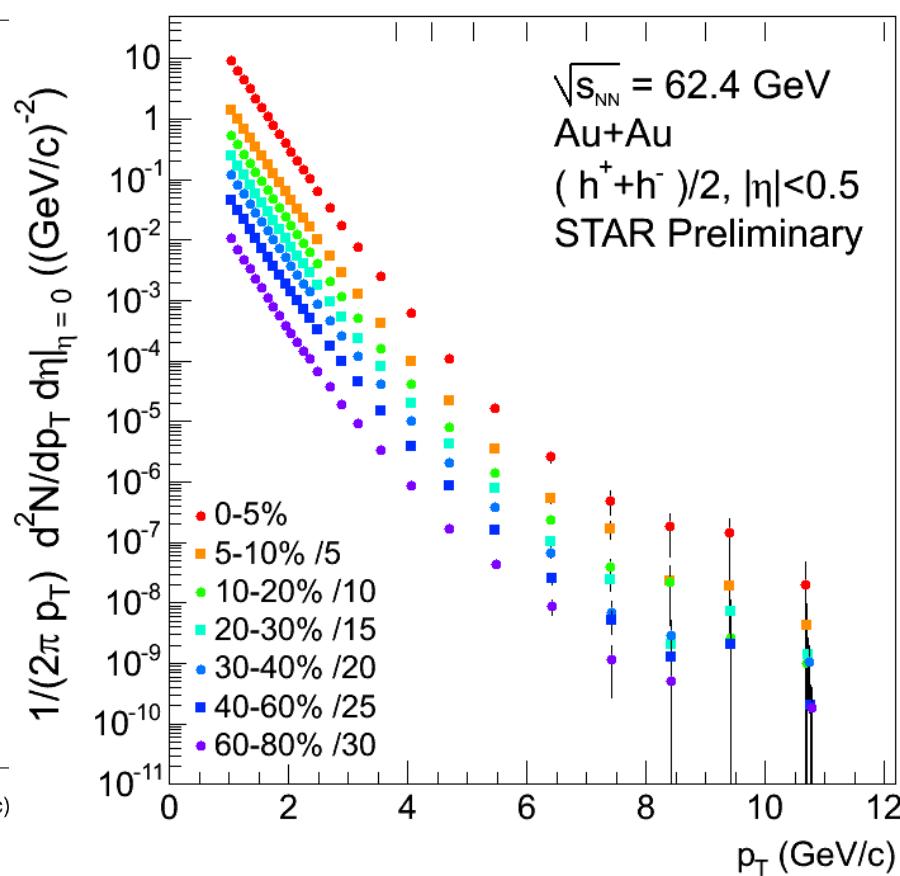
University of Bern

# Charged hadron spectra @ 62 GeV

*p+p reference from ISR*



*Au+Au from STAR*



**Both p+p reference and Au+Au spectra out to ~12 GeV/c**

**1/3 of the Au+Au dataset analyzed**